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Prediction of traffic noise: part 2

Definitive formulae

Calculations using even the large working-size charts referred to in Part 1 of this digest may result in an overall error of around 1 dB(A) due to the errors in chart reproduction and chart reading. For many situations this kind of error will be acceptable but when a higher degree of accuracy is required, the calculation should be based on the definitive formulae given below. Such a case would occur in the context of the Noise Insulation Regulations 1973 if the evaluation gave a result in the critical region of 66 to 69 dB(A) or in assessing a 1 dB(A) increase.

Where appropriate the chart numbers in Part 1 of this digest associated with the respective formulae are given. All the corrections are to be added to the 10 m noise level.

10 m noise level (Fig 1)

(i) L_{10} (18 h) = 28·1 + 10 log Q. dB(A)

(ii) L_{10} (1 h) = 41·2 + 10 log q. dB(A)

where Q = total vehicle flow, 06·00 to 24.00 hours

q = total vehicle flow within the hour.

Correction for mean traffic speed and traffic composition (Fig 2)

$$\text{Correction} = 33 \log \left(v + 40 + \frac{500}{v}\right) + 10 \log \left(1 + \frac{5p}{v}\right) - 68{\cdot}8 \text{ dB(A)}$$

where v = mean speed of all the traffic, km/h, during relevant period

p = percentage of heavy vehicles in traffic flow during relevant period.

Gradient

Correction = 0·3 G when actual mean speed is used

Correction = 0·2 G when design speed of road is used, see Traffic speed,

where G = percentage gradient.

Correction for surfaces with 5 mm or more deep random grooving

Correction = 4 −0·03p

where p = percentage of heavy vehicles.

Distance (hard ground) (Fig 3)

$$\text{Correction} = -10 \log \frac{d'}{13{\cdot}5} \text{ dB(A)}$$

where d' = slant distance, in metres, between reception point and source line (0·5 m high and 3·5 m in from nearside edge of road) measured perpendicularly to source line.

$$\text{ie } d' = \left[(d + 3{\cdot}5)^2 + (h - 0{\cdot}5)^2\right]^{\frac{1}{2}}$$

where d = horizontal distance, in metres, between reception point and nearside edge of road

h = height, in metres, of reception point above road surface

This correction is valid for d' > 4 m.

Distance (grassland) (Fig 4)

(i) for $h > \frac{d + 3{\cdot}5}{3}$ Correction =

$$-10 \log \frac{d'}{13{\cdot}5} \text{ dB(A)}$$

(ii) for $1 \leq h \leq \frac{d + 3{\cdot}5}{3}$ Correction =

$$-10 \log \frac{d'}{13{\cdot}5} + 5{\cdot}2 \log \left[\frac{3h}{d + 3{\cdot}5}\right] \text{dB(A)}$$

Screening by very long barrier (Fig 5)

$$\text{Correction} = A_0 + A_1 x + A_2 x^2 + \ldots\ldots\ldots + A_n x^n \text{dB(A)}$$

where x = log (a + b − c), (a + b − c) being the path difference in metres (see Fig 5), and

$A_0, A_1 \ldots\ldots A_n$ are constants given in the following table.

	Shadow zone	Illuminated zone
A_0	−15·4	0
A_1	− 8·26	+0·109
A_2	− 2·787	−0·815
A_3	− 0·831	+0·479
A_4	− 0·198	+0·3284
A_5	+ 0·1539	+0·04385
A_6	+ 0·12248	
A_7	+ 0·02175	
Range of validity	$-3 \leq x \leq +1{\cdot}2$	$-4 \leq x \leq 0$

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Technical enquiries arising from this Digest should be directed to Building Research Advisory Service at the above address.

Outside these ranges of validity the correction is defined as follows

Shadow zone		Illuminated zone	
For $x < -3$	$A = -5{\cdot}0$	For $x < -4$	$A = -5{\cdot}0$
For $x > 1{\cdot}2$	A is not defined	For $x > 0$	$A = 0$

The illuminated zone in the table refers to the region in which the source can just be seen from the reception point, over the top of the barrier. In this case the use of constants above A_5 is not necessary. In the shadow zone it is not necessary to use constants beyond A_7.

Angle of view (Fig 8)

$$\text{Correction} = 10 \log\left(\frac{\theta}{180}\right) \text{dB(A)}$$

where θ = the angle of view of the segment, in degrees.

Combination of noise levels (Fig 9)

Given two noise levels, L_1 and L_2 dB(A), L_1 being higher than or equal to L_2, the total combined noise level is determined by adding a correction to L_1.

$$\text{Correction} = 10 \log\left[1 + 10^{\frac{(L_2 - L_1)}{10}}\right] \text{dB(A)}$$

Degradation of screening by retained cuttings (Fig 10)

$$\text{Correction} = F \times D \quad \text{dB(A)}$$

where D = depth of cutting, in metres
$F = \exp(-0{\cdot}019\,\phi^2)$
ϕ = the angle of the cutting walls to the vertical, in degrees.

Barrier design

The principle of barrier design is to provide as large an acoustic shadow as possible. The further the reception point is within the shadow the greater will be the noise reduction. For maximum noise reduction, barriers should be as high and as long as possible and as close to the source or the receiver as possible. Barriers to reduce traffic noise will generally be constructed close to the road. Screening corrections, appropriate to particular configurations, may be determined using the methods given in Part 1 of this digest. Throughout, it is assumed that the sound transmitted through the barrier is negligible compared with that passing over or round it: the barrier should, therefore, resist the transmission of sound. It should be largely imperforate but not necessarily of massive construction. The potential screening A (from Figs 5 and 6) is used to determine the minimum desirable mass per unit area, M, of a single leaf barrier or of one of the leaves of a multi-leaf barrier.

In general, $M = 3 \times 10^{-\left(\frac{A+10}{14}\right)}$ kg/m²

Note that the potential screening corection, A, is negative, so for

$A = -17$ dB(A), $M = 3 \times 10^{1} = 9{\cdot}5$ kg/m²

As a rough practical guide the following values of M are suggested:

For A between 0 and −10 dB(A) M = 5 kg/m²
For A between −10 and −15 dB(A) M = 10 kg/m²
For A between −15 and −20 dB(A) M = 20 kg/m²

Thus, for a barrier to achieve its full potential screening of, say, −10 dB(A) it would require a superficial mass of about 5 kg/m²; 12 mm plywood, at 6 kg/m² would, therefore, be more than adequate.

Other factors to be considered in barrier design include appearance, safety, durability and wind loading.

Traffic speed

General information on future mean speeds for different types of road is given in 'Calculation of road traffic noise'[2]. These data are to be used in determining eligibility for sound insulation treatment under the regulations[3] except that where based on knowledge of particular local conditions, the highway authority's estimate of traffic speed at a location differs significantly from that prescribed, then the highway authority's estimate must be used.
The generalised estimates of traffic speed from reference[2] are given below.

Roads not subject to a speed limit of less than 60 mph

Special roads (rural) excluding slip roads	108 km/h
Special roads (urban) excluding slip roads	97 km/h
All-purpose dual carriageways excluding slip roads	97 km/h
Single carriageways, more than 9 m wide	88 km/h
Single carriageways, 9 m wide or less	81 km/h

(Slip roads are to be estimated individually)

Roads subject to a speed limit of 50 mph

Dual carriageways	80 km/h
Single carriageways	70 km/h

Roads subject to a speed limit of less than 50 mph but more than 30 mph

Dual carriageways	60 km/h
Single carriageways	50 km/h

Roads subject to a speed limit of 30 mph or less

All carriageways	50 km/h

It is only in urban areas where mean speeds of less than 50 km/h will be found over 18 hours and in most cases the range within this period is sufficiently variable to allow the use of the 50 km/h mean speed.

Worked example

The application of the prediction procedure, given in Part 1 of this digest, is illustrated for the fairly simple situation shown below. It is assumed that the L_{10} (18 hour) level at the reception point R is required. R is 1 m from the facade at a height of 6 m.

The traffic flow, Q, is taken to be 30,000 v/18 hour day, of which the percentage of heavy vehicles, p, is 35 per cent. The mean speed, v, is 90 km/h. It is further assumed that the whole site is flat and mainly grassland and that there is no road gradient. The barrier is 3 m high and 5 m from the edge of the single carriageway road. There is a bend in the unscreened part of the road.

This situation requires three segments: X, Y and Z.
Segment X, angle 70°, covers the part of the road screened by the barrier.
Segment Y, angle 60°, covers the road between the end of the screened section and the bend
and Segment Z, angle 40°, covers the road beyond the bend.

Step 1: 10 m noise level

From Fig 1: for Q of 30,000 v/18 hour day, L_{10} (18 hour)	= 72·8 dB(A)
From Fig 2: for v = 90 km/h and p = 35%; correction	= + 6·3 dB(A)
There is no road gradient, therefore 10 m noise level	= 79·1 dB(A)

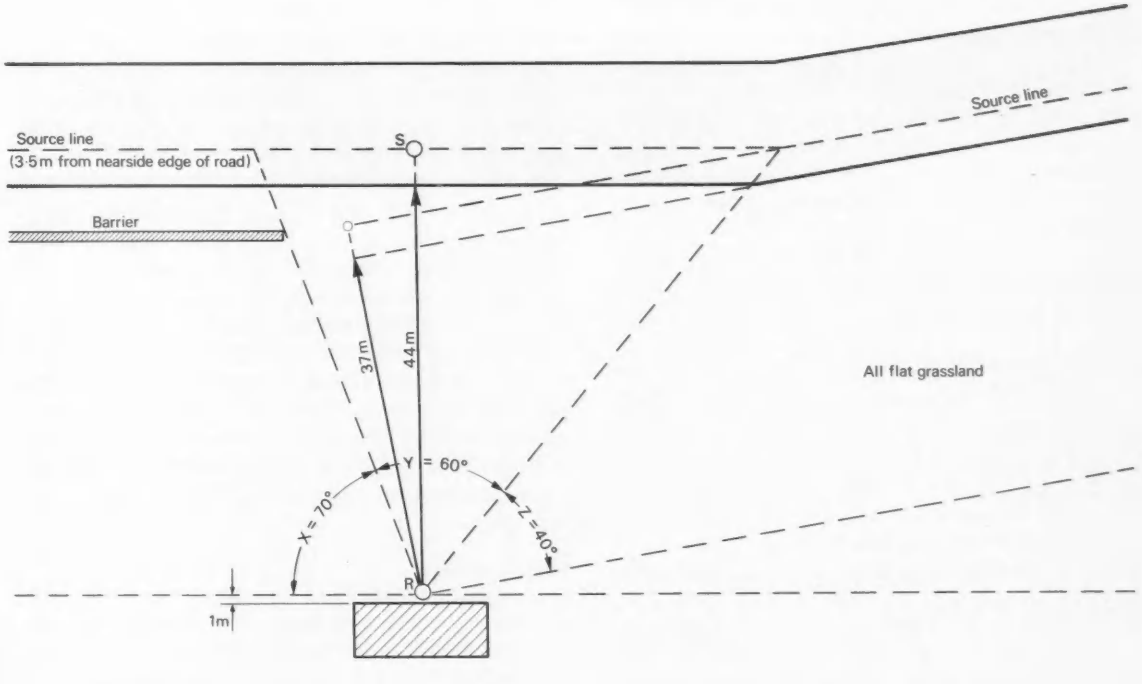
Step 2: Contribution of segments

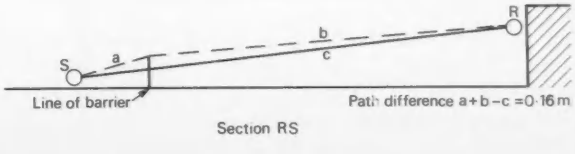
(i) Segment X

Horizontal distance between reception point and extension of the edge of the screened part of the road = 44m;
reception point height = 6 m;
barrier height = 3 m;
angle of segment = 70°

Because screening applies in this segment, the hard ground distance correction must be applied to the 10 m noise level together with the screening correction to obtain the screened noise level; a further correction must be applied for angle of view because the screening does not operate over the full 180°.

From Fig 3 (hard ground, because there is screening): distance and height correction	= −5·5 dB(A)





Section RS

From Fig 5: calculate path difference from a section perpendicular to extended line of barrier, 0·16 m, and obtain screening correction (see inset on figure) = −10·4 dB(A)

From Fig 8: enter 70° (angle of segment X) to determine angle of view correction = −4·0 dB(A)

Total correction to be applied to 10 m noise level for segment X = −19·9 dB(A)

Contribution of segment X = 79·1 −19·9 = 59·2 dB(A)

(ii) Segment Y

Horizontal distance from reception point to edge of road = 44 m

Reception point height = 6 m

Angle of segment = 60°

From Fig 4 (grassland): distance and height correction = −7·5 dB(A)

From Fig 8: enter 60° (angle of segment Y) to determine angle of view correction = −4·8 dB(A)

Total correction to be applied to 10 m noise level for segment Y = −12·3 dB(A)

Contribution of segment Y = 79·1 −12·3 = 66·8 dB(A)

(iii) Segment Z

Horizontal distance from reception point to the extension of the edge of the road within this segment = 37 m

Reception point height = 6 m

Angle of segment = 40°

From Fig 4 (grassland): distance and height correction = −6·4 dB(A)

From Fig 8: enter 40° (angle of segment Z) to determine angle of view correction = −6·5 dB(A)

Total correction to be applied to 10 m noise level for segment Z = −12·9 dB(A)

Contribution of segment Z = 79·1 −12·9 = 66·2 dB(A)

Step 3: Combination of contributions from segments

Segment X contributes 59·2 dB(A)
Segment Y contributes 66·8 dB(A)
Segment Z contributes 66·2 dB(A)

Combining the contributions from segments X and Y first (the order of combination is unimportant):

Difference between X and Y = 66·8 −59·2 = 7·6 dB(A)

From Fig 9: correction to be added to higher level = +0·7 dB(A)

Combined level = 66·8 + 0·7 = 67·5 dB(A)

Combine this level with Z:

Difference between combined level and Z = 67·5−66·2 = 1·3 dB(A)

From Fig 9: correction to be added to higher level = +2·4 dB(A)

Total for all segments = 67·5 + 2·4 = 69·9 dB(A)

This is the free field noise level with no allowance for reflections.

Step 4: Reflections

The reception point is 1 m from a facade and there are no buildings lining the road on the far side. A correction of +2·5 dB(A) applies for the facade effect.

Final result: L_{10} (18 hour) at reception point = 69·9 + 2·5 = 72·4 dB(A).

In this example, the working-size charts published in 'Predicting road traffic noise' were used. Figure 5 was used to determine the screening correction, which involves a subsidiary calculation of the path difference (a + b − c) and which gives a correction of −10·4 dB(A). Alternatively, the use of the nomogram, Fig 6, and a scale drawing results in a screening correction of −10·3 dB(A). Such a close agreement may not always be obtained; generally an accurate determination of the path difference and the use of Fig 5 will give a more accurate result than the use of Fig. 6. The highest accuracy will result from the use of the definitive formulae with an accurate determination of path difference. In this worked example, the final result using the formulae throughout is 72·2 dB(A) compared with 72·4 dB(A) from the charts (irrespective of whether Fig 5 or Fig 6 is used).

References

1 Predicting road traffic noise; HMSO
2 Calculation of road traffic noise; 1975; HMSO; £1.70
3 Noise insulation regulations; 1975; HMSO

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